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ENT

Originals

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F. Sommer[1] · A.-S. Grossi[1] · MO Scheithauer[1] · TK Hoffmann[1] · F. Stupp[1] · HR Briner[2] · J. Lindemann[1]

[1]Department of Otorhinolaryngology, University Hospital Ulm, Ulm, Germany

[2]Hirslanden Hospital, Zurich, Switzerland

Negative effects of strip conchotomy on intranasal air conditioning

Background and question

Surgery on the inferior turbinates is often performed routinely as a complementary procedure during functional nasal surgery. Over the past century, many different surgical techniques have been described to reduce the size of the turbinates [1]. A distinction is made

- thermal and radio frequency drive and
- surgical-resecting procedures.

Each technique has advantages and disadvantages. However, extensive resections of the inferior turbinate often lead to empty nose syndrome [1–3]. When selecting the preferred technique, the physiological functions of the inferior turbinates in the context of intranasal air conditioning must be considered. These include the regulation of respiratory resistance and thus the distribution of inhaled air across the nasal cross-section (diffuser), as well as enlargement of the mucosal surface area, reduction of nasal volume, formation of cleft spaces, humidification, and warming of the incoming air. Extensive resections of the nasal turbinates negatively affect all of these functions, as demonstrated in numerical simulations of intranasal air flow and air conditioning [4,5Radical operations on the nasal turbinates should now only be performed in Neoplasias in this area [6].

Nevertheless, even today, the "strip conchotomy" is still performed, sometimes routinely, as part of functional nasal surgery. In addition to an increased risk of bleeding with severe crust formation and a prolonged healing process, this has negative effects on intranasal airflow and the conditioning of the inhaled air [7]. In this procedure, the inferior turbinate is first crushed and a strip of mucosa, including the mucous part of the turbinate head, is resected with septal scissors (.**Fig.1and2**Depending on the extent of the resection, the caudal portions of the turbinal bone are also removed. The caudal mucosal and cavernous portions of the turbinate are resected independently. The popularity of this procedure is likely due to its rapid performance. However, its negative impact on the distribution of air in the nose is often overlooked.

To date, no numerical simulations using Computational Fluid Dynamics (CFD) have been published on nasal airflow, temperature, and humidity distribution after strip conchotomy.

The aim of this numerical study was to investigate the effects of a partial resection of the inferior turbinate in the sense of a strip conchotomy on nasal airflow, temperature and humidity distribution during a breathing cycle using CFD.

These are able to visualize the effects of turbinate resections on the flow dynamics in the nasal cavity [8–11]. For this purpose, a computed tomography (CT) scan of the paranasal sinuses of a patient who had undergone external unilateral partial resection of the inferior turbinate 2 years previously was used.

Study design and Examination methods

Model description

A three-dimensional virtual model of the nasal cavity and paranasal sinuses was constructed from this CT dataset of a patient with a unilateral strip conchotomy condition.

As in.**Fig.3**As can be seen, the patient had undergone a partial resection of the inferior turbinate on the right side, including part of the turbinate head. The nasal septum was straight, and the remaining turbinates were of normal configuration. The mucosa showed no signs of chronic sinusitis. The CT scan was performed to rule out chronic sinusitis due to typical symptoms. The CT examination was performed on a Siemens Somatom Definition CT scanner (Siemens Healthcare GmbH, Erlangen, Germany) with a slice thickness of 0.6 mm.

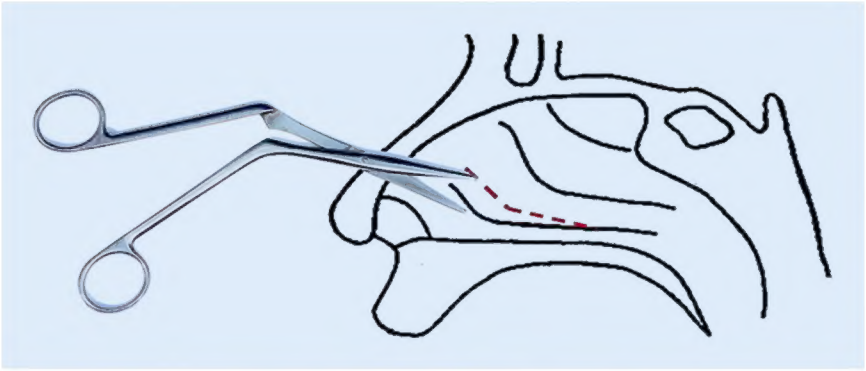

Fig. 18Strip conchotomy with resection of the turbinate head and a strip of mucous membrane by scissors along the*dotted line*

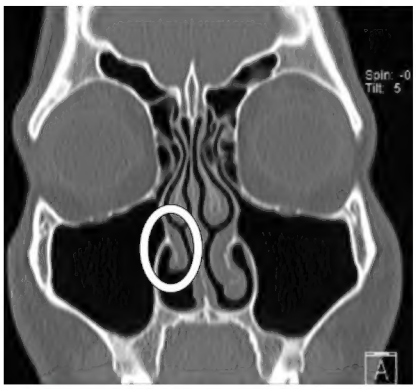

Fig. 38Computed tomography scan of a patient with a condition following unilateral partial resection of the right inferior turbinate (*white circle*)

Software and model creation

The free, open-source software ITK-SNAP (v. 3.0.0) was used to segment the CT dataset. A virtual mesh with 3.1 million cells was generated around the surface model. Numerical simulation was performed using the CFD solver Fluent (ANSYS Workbench 14, ANSYS, Inc., Canonsburg, PA, USA).

The boundary conditions of the simulations were based on results from the authors' own in vivo measurements. Various static nasal airflow velocities were simulated and analyzed. The simulation was performed in a transient setting. Our own in vivo measurements served as the basis for the boundary conditions used in the virtual model.4,5].The respiratory cycle was defined by the inspiratory and expiratory pressure at the nasopharynx.

Inhaled air had a temperature of 20°C and 30% relative humidity, while exhaled air had a temperature of 37°C and 100% relative humidity. A complete breathing cycle lasted 4.2 seconds. Inspiration took 2 seconds, and expiration 2.2 seconds.

Results

The flow distribution, air temperature and humidity in the nasal cavity are shown by cross-sectional planes at 1.6 s at the end of inspiration (.**Fig.4**).

With regard to air velocity, a significant difference was observed between the non-operated left nasal cavity and the right one with partial resection of the inferior turbinate. On the left side, a homogeneous velocity distribution was found in the nasal cavity, with a moderate maximum velocity of up to 1.5 m/s. The right side showed a significantly increased velocity in a tube-like formation in the area of the former head and body of the inferior turbinate, with a velocity of up to 2 m/s. Furthermore, the flow velocity in the upper parts of the nasal cavity was significantly lower compared to the non-operated side. This tube-like airflow is still clearly visible in the nasopharyngeal region (.**Fig.4**, picture top right).

During inspiration, the mucous membrane of the lateral nasal wall and the nasal septum warms the incoming cool air. A clear

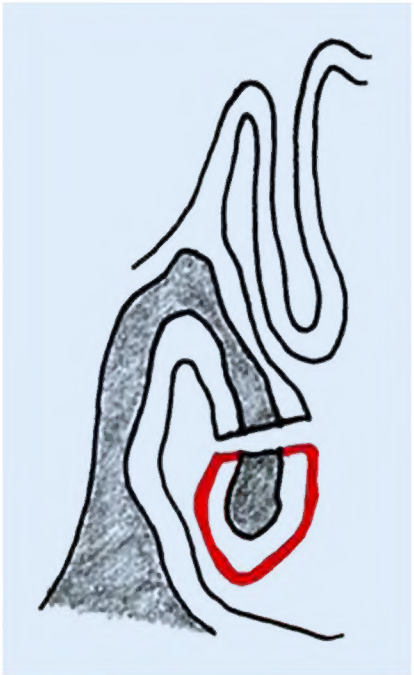

Fig. 28Coronal schematic drawing of the resection area of a strip conchotomy (here including part of the os turbinale). (From [18], with kind permission of Georg Thieme Verlag, Stuttgart)

An increase in air temperature was observed near the nasal wall. The nasal turbinates are responsible for a large portion of heat exchange during inspiration. A significant difference in air temperature distribution was observed between the left, non-operated side and the right side with partial resection of the inferior turbinate, extending into the nasopharynx. The temperature increase along the inferior meatus was significantly smaller compared to the contralateral side. The cool center of the airflow was larger on the right side compared to the left side. This asymmetric temperature distribution was evident as far as the nasopharynx.

Almost identical to the measurements of air distribution and temperature, a significant difference in intranasal humidity was detected between the right and left nasal cavities. In the left nasal cavity, the airflow velocity was homogeneous, and the air temperature in the center of the airflow reached higher values.

and higher humidity levels were detected near the wall. On the right side, partial resection of the inferior turbinate resulted in a "tube-like" lower nasal passage. Airflow in this area is significantly faster, and the temperature is cooler in the center of the airflow. Additionally, the humidification of the inhaled air drops from nearly 100% to approximately 80%, which also has an impact in the nasopharyngeal region.

discussion

Chronic nasal breathing obstruction caused by a hypertrophic inferior turbinate can be treated by various techniques of turbinate plastic surgery [12]. Therefore, turbinate plastic surgery is a very frequently performed surgical procedure. It is often performed as part of functional nasal surgery.

Computational fluid dynamics is currently the only way to perform high-resolution analyses of flow, temperature, and humidity distribution in the nose. These simulations or approximations are based on computational models that have been standardly used in industry for many years. Numerous publications have demonstrated that their use in rhinology is feasible and delivers valid results [13–17].

The results presented here are the analysis*one*virtual realistic model. The present case was selected because a unilateral strip conchotomy had been performed by an external ENT colleague, but otherwise the findings were approximately symmetrical, and a CT of the paranasal sinuses was available in addition to the evaluation of sinus symptoms. Despite being "only" one case, the numerical results are suitable for demonstrating the overall effects on nasal perfusion due to the symmetrical findings of the main nasal cavity.

How.**Fig.5**shows, the right-sided strip conchotomy results in a visibly increased respiratory flow compared to the

Summary · Abstract

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Negative effects of strip conchotomy on intranasal air conditioning

Summary

Goal. Partial resection of the caudal portion of the inferior turbinate, including the turbinate head, is still a common procedure in rhinosurgery ("strip conchotomy"). However, extensive resections of the turbinate impair nasal airflow and intranasal conditioning. The aim of this study was to determine the effect of partial resection of the inferior turbinate, including the turbinate head, on intranasal airflow, as well as on heating and humidification of the incoming air, using computational fluid dynamics.

Materials and methods. Based on a patient's computed tomography dataset, a bilateral realistic nasal model was created. Unilateral partial resection of the right inferior turbinate was performed externally, while the left inferior turbinate was preserved. Numerical simulations were performed to analyze intranasal airflow patterns, inspired air temperature, and humidity distribution.

Results. Due to the partial resection of the inferior turbinate on the right side, including the turbinate head, the flow pattern was significantly altered compared to the contralateral side. The resection resulted in a more centered and higher velocity in the inferior meatus, as well as reduced warming and humidification of the inspired air compared to the non-operated left nasal cavity.

Conclusion. The frequently performed partial resection of the caudal portion of the inferior turbinate can lead to impaired intranasal conditioning if extensive resection is performed. Therefore, this procedure should be avoided in rhinosurgery whenever possible, and a more mucosal-sparing approach should be chosen instead.

Keywords

Nasal turbinates · Surgical procedures · Nasal cavity · Nasal surgeries · Computer simulations

Negative effects of stripe conchotomy on intranasal conditioning

Abstract

Objective. Partial resection of the caudal part of the inferior turbinate including the head is still performed in rhinosurgery ("stripe conchotomy"). However, extensive resections of the turbinate affect nasal airflow and intranasal conditioning. The aim of this study was to determine the effect of partial resection of the inferior turbinate including its head on intranasal air flow as well as warming and humidification of the inspired air by means of computational fluid dynamics. **Materials and methods.**A bilateral, realistic nasal model was created based on the CT scan of a patient. A unilateral partial resection of the lower turbinate on the right side had been performed externally. A numerical simulation was performed to analyze intranasal air flow patterns, temperature, and humidity distribution of the inspired air.

Results. Due to the partial resection of the lower turbinate on the right side, the flow pattern was significantly altered compared to the opposite side. Resection leads to a centered and higher velocity in the inferior nasal meatus as well as to reduced heating and humidification of the inhaled air compared to the untouched left nasal cavity. **Conclusion.**Partial resection of the caudal part of the inferior turbinate may lead to disturbed intranasal conditioning of inspired air if performed too radically. Therefore, if possible, this procedure should be avoided and a more gentle mucosal procedure chosen.

Keywords

Turbinates · Surgical procedures, operative · Nasal cavity · Nasal surgical procedures · Computer simulation

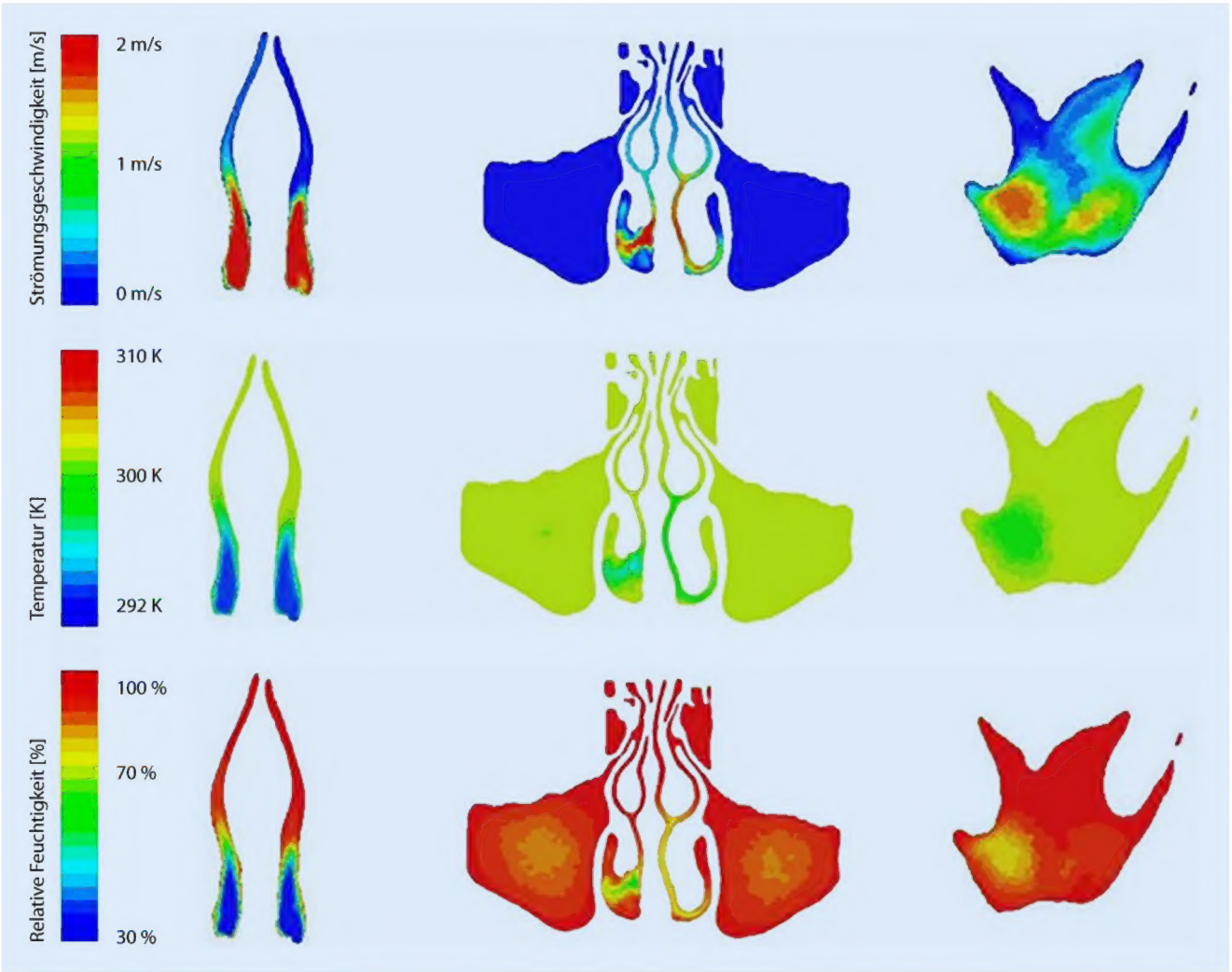

Fig. 48Color-coded distribution of flow velocity, air temperature, and relative frequency along the nasal cavity using coronal slices (anterior to posterior)

In addition to creating a widened cleft space, the preservation of the physiological function of the nasal turbinates and their function (warming and humidifying the respiratory air) should be the main goal of turbinate surgery [18The balance between sufficient tissue reduction to relieve obstructive symptoms and sufficient preservation of mucosal tissue to prevent crusting and mucosal desiccation is a crucial prerequisite in turbinate surgery. Partial resection of the inferior turbinate, such as a strip conchotomy, not only reduces nasal inspiratory resistance but also improves the respi-

functional function of the nose, as large parts of the surface or mucous membrane of the turbinate are removed.

The nasal valve is a physiological constriction that is crucial for efficient humidification and warming of the inhaled air [4,5,8–10 Hypertrophy of the lateral nasal wall and the inferior turbinate can lead to significant nasal obstruction. Grützenmacher et al. demonstrated in various nasal models with varying degrees of resection that a partial reduction of the inferior and, if necessary, the middle turbinate can lead to a reduction in inspiratory resistance while still maintaining a physiological distribution of inspired air.

can, provided the resection is moderate [19]. Lindemann et al. showed that very extensive turbinate resections lead to disturbed intranasal airflow and thus the air conditioning function of the nose is fundamentally impaired [4,5,9,10,20].

In a clinical study by Tsakiropoulou et al., 57 patients who underwent partial inferior turbinate resection were examined [21]. Here, too, spot in vivo measurements revealed a decrease in temperature in the inferior and middle nasal conchae by 13 and 19%, respectively. However, there was no significant decrease in relative humidity, which would have been expected. Here, the absolute humidity would have had to be calculated, since

Obstruktion (Resistance)	Durchgängigkeit (Conductance)	Log 10 R (VR, Reff)	Flow bei 150 Pa [ccm/s]
keine	sehr gut	< 0.75	> 500
gering	gut	0.75 - 1.00	300 - 500
mäßig	mäßig	1.00 - 1.25	180 - 300
hoch	schlecht	1.25 - 1.50	60 - 180
sehr hoch	sehr schlecht	> 1.50	< 60

Standardwerte (ISOANA):

Zeit	15:32:02			15:38:48		
.	Rechts	Links	Total	Rechts	Links	Total
[Pa]	[ccm/s]	[ccm/s]	[ccm/s]	[ccm/s]	[ccm/s]	[ccm/s]
75 ins.	166	122	288	172 /3%	193 /58%	365 / 26%
150 ins.	290	217	507	325 /12%	330 /52%	655 / 29%
SQ 150		1.34			1.02	
75 ex.	-173	-129	-302	-215 /24%	-261 /102%	-476 / 57%
150 ex.	-257	-193	-450	-327 /27%	-385 /99%	-712 / 58%
SQ 150		1.33			1.18	
subject.	50	50		50	50	
log Reff Ins.	0.95	1.17		0.86	0.82	
log Reff Exp.	0.90	1.04		0.74	0.71	
log Reff total	0.92	1.11		0.80	0.77	
log VR ins.	0.89	1.14		0.86	0.84	
log VR exp.	0.93	1.09		0.76	0.74	
Freq.[1/min]	11.8	12.3		11.0	12.9	

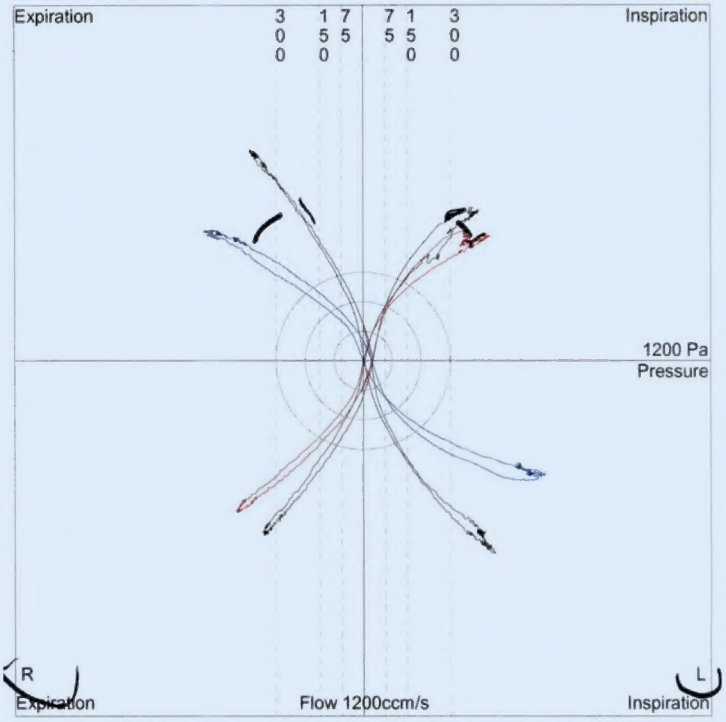

Fig. 58Four-phase rhinomanometry of the patient after external strip conchotomy. Significantly increased flow and reduced swelling of the right turbinate body.

This indicates the humidity level as a function of temperature. An in vivo measurement in the nasopharynx would likely have shown the reduced humidity. However, this is difficult to achieve because both the probe and the cable connected to it influence the measured values. A temperature or humidity distribution in a three-dimensional space cannot be represented with in vivo measurements, since only individual measurement points are recorded.

The aerodynamic effects of a partial resection in the sense of a strip conchotomy of the inferior turbinate involving the turbinate head as part of the nasal valve have not yet been numerically investigated. The aim of this study was to evaluate the flow dynamics, air temperature and
- to demonstrate moisture distribution after partial turbinectomy in the sense of a strip conchotomy over the entire nasal cavity.

As demonstrated, the air temperature and humidity distribution is significantly altered during inhalation. Significantly lower Temperature and relative humidity values of the inhaled air on the surgically treated side of the numerical nasal model. This can be explained by disturbed air flow dynamics with a diversion of the main airflow through the inferior nasal meatus. In addition, there is the loss of mucosal surface and turbinate volume as a heat source. This leads to reduced humidification and warming of the inhaled air. Furthermore, the increase in air temperature depends on the flow velocity, the cross-sectional area, and the temperature difference between the air and the walls of the "flow tube" [22]. Lindemann et al. showed that in a healthy, non-operated nose, regions with low flow velocities exhibit air turbulence around the nasal turbinates, which leads to a significant increase in air temperature during inspiration [4After a strip conchotomy with partial resection of the turbinate head as part of the nasal valve, the flow velocity in the inferior nasal meatus increases significantly. Only a very narrow layer of air directly along the nasal wall comes into contact with the mucosal surface. The center of the airflow in the entire lower nasal passage remains cool. CFD simulations clearly show that due to the higher flow velocities and the essentially laminar airflow, the central airflow does not come into sufficient contact with the mucosal surface to warm or moisten. The middle and upper nasal passages receive only insignificant airflow after strip conchotomy and therefore no longer participate in the conditioning of the incoming air (.**Fig.4**These changes in air velocity, temperature, and humidity are traceable in the computer model down to the nasopharynx. The significant decrease in air temperature on the operated side leads to a decrease in the maximum water vapor capacity, which is reflected in a decrease in relative humidity on the right side.

assessment

The authors believe that partial resection of the inferior turbinate with resection of the turbinate head as part of the nasal valve (strip conchotomy) is performed too frequently and significantly disrupts intranasal conditioning. If too much turbinate tissue is resected, this often leads to empty nose syndrome, which severely restricts nasal respiratory function. Due to the excessively reduced nasal resistance, the main airflow is redirected exclusively to the inferior meatus. The radical reduction of the inferior turbinate volume leads to a "tunnel-like" airflow, which significantly reduces air contact with the mucosa and leads to significantly lower temperature and humidity in the nasopharynx on the affected side. Since adequate air conditioning through the nose is required for breathing in the lower respiratory tract, strip conchotomy, especially when performed bilaterally, can have a negative impact on nasal physiology. In view of the presented numerical simulation results, strip conchotomy should not be performed to reduce the size of the turbinates. Instead, methods should be preferred that leave the mucosal surface as intact as possible and do not radically reduce the turbinate volume.

Conclusion for practice

- **Partial resection of the lower nasenmuschel with resection of the mussel head significantly disrupts intranasal air conditioning.**
- **If nasal discharge is too reduced, resistance, the main air flow is redirected exclusively to the lower nasal passage.**
- **The "tunnel-like" air flow after strip conchotomy leads to reduced contact of air with the mucosa.**
- **This leads to reduced Temperature and humidity in the nasopharynx of the affected side.**
- **Therefore, strip conchotomy should to reduce the nasal turbinates should not be performed.**
- **Methods appear to be more suitable, in which the mucous membrane surface is left as intact as possible.**
- **The shell volume should not be radically reduced.**

Correspondence address

PDDr. F. Sommer
Department of Otorhinolaryngology,
University Hospital Ulm
Frauensteige 12, 89075 Ulm, Germany
fabian.sommer@uniklinik-ulm.de

Compliance with ethical guidelines

Conflict of interest. F. Sommer, A.-S. Grossi, MO Scheithauer, TK Hoffmann, F. Stupp, HR Briner and J. Lindemann declare that no conflict of interest exists.

This article does not contain any studies on humans or animals conducted by the authors.

literature

1. Huizing E, De Groot J (2003) Functional Reconstructive Nasal Surgery
2. Passàli D, Passàli FM, Damiani V et al (2003) Treatment of inferior turbinate hypertrophy: a randomized clinical trial. Ann Otol Rhinol Laryngol112:683–688
3. Scheithauer MO (2010) Surgery of the turbinates and "empty nose" syndrome. GMS Curr Top Otorhinolaryngol HeadNeckSurg9:Doc3.https://doi.org/10.3205/cto000067
4. Lindemann J, Keck T, Wiesmiller KM et al (2005) Numerical simulation of intranasal air flow and temperature after resection of the turbinates. Rhinology43:24–28
5. Lindemann J, Brambs HJ, Keck T et al (2005) Numerical simulation of intranasal airflow after radical sinus surgery.AmJOtolaryngol26:175–180
6. Sommer F, Lindemann J, Scheithauer MO et al (2017) Turbinate surgery. HNO 65:443–456. https://doi.org/10.1007/s00106-017-0349-5
7. Sinno S, Mehta K, Lee ZH et al (2016) Inferior turbinate hypertrophy in rhinoplasty. Plast Reconstr Surg138:419e–429e.https://doi.org/10.1097/PRS.0000000000002433
8. Ozlugedik S, Nakiboglu G, Sert C et al (2008) Numerical study of the aerodynamic effects of septoplasty and partial lateral turbinectomy. Laryngoscope 118:330–334.https://doi.org/10.1097/MLG.0b013e318159aa26
9. SommerF,KrögerR,LindemannJ(2012)Numerical simulation of humidification and heating during inspiration within an adult nose. Rhinology 50:157–164
10. Lindemann J, Rettinger G, Kröger R, Sommer F (2013) Numerical simulation of airflow patterns in nose models with differently localized septal perforations. Laryngoscope 123:2085–2089. https://doi.org/10.1002/lary.23653
11. Sommer F, Hoffmann TK, Mlynski Getal (2017) Three-dimensional analysis of nasal physiology. HNO 66:280–289.https://doi.org/10.1007/s00106-017-0443-8
12. HolMK,HuizingEH(2000)Treatmentofinferiorturbinate pathology: a review and critical evaluation ofthedifferenttechniques.Rhinology38:157–166
13. Keck T, Lindemann J (2010) Numerical simulation and nasal air-conditioning. GMS Curr Top Otorhinolaryngol Head Neck Surg 9:Doc8.https://doi. org/10.3205/cto000072
14. Chen XB, Lee HP, Chong VF, de Wang Y (2010) Impact of inferior turbinate hypertrophy on the aerodynamic pattern and physiological functions of the turbulent airflow—aCFD simulation model. Rhinology 48:163–168.https://doi.org/10.4193/Rhin09.093
15. PlessD,KeckT,WiesmillerKMetal(2004)Numerical simulation of airflow patterns and air temperature distribution during inspiration in a nose model with septal perforation.AmJRhinol18:357–362
16. ChenXB,LeongSC,LeeHPetal(2010)Aerodynamic effects of inferior turbinate surgery on nasal airflow—a computational fluid dynamics model. Rhinology 48:394–400.https://doi.org/10.4193/Rhin
17. Chen AmJRhinolAllergy24:e118–e122
18. Scheithauer MO (2010) Surgery of the turbinates and "empty nose" syndrome. Laryngorhinotology89:S79–S102.https://doi.org/10.1055/s-0029-1246126
19. Grützenmacher S, Lang C, Mlynski G (2003) The combination of acoustic rhinometry, rhinoresistometry and flow simulation in noses before and after turbinate surgery: a model study. ORL J OtorhinolaryngolRelatSpec65:341–347
20. LindemannJ,LeiackerR,SikoraTetal(2002) Impact of unilateral sinus surgery with resection of the turbinates by means of midfacial degloving on nasal air conditioning.Laryngoscope112:2062–2066
21. Tsakiropoulou E, Vital V, Constantinidis J, Kekes G (2015) Nasal air-conditioning after partial turbinectomy: myths versus facts. Am J Rhinol Allergy 29:e59–e62.https://doi.org/10.2500/ajra.2015.29.4151
22. Hering E, Martin R, Stohrer M (2012) Physics for Engineers. Springer, Berlin-Heidelberg